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A SURVEY ON MACHINE LEARNING IN WIRELESS SENSOR NETWORKS

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ABSTRACT

The sensors in Wireless Sensor networks gather data about the objects they are used to sense . However these sensors are limited in their performance by constraints of energy and bandwidth. Machine Learning techniques can help them in overcoming such constraints. This survey paper surveys machine learning techniques which have been used to improve the working efficiency of such networks especially with respect to the above two constraints. The emphasis is on Applications and the paper also discusses emerging directions for further research work in this area.

KEYWORDS: Wireless Sensor Networks(WSNs), Machine Learning Techniques,WSN applications.

I. Introduction

A Wireless Sensor Network is a self-configuring network of small sensor nodes communicating among themselves using radio signals and are deployed in quantity to sense, monitor and interpret the physical world.

They have a wide range of potential applications in industry, science, transportation, civil infrastructure and security. This has attracted wide attention from researchers. In particular, research stress has been on the networking related aspects like routing strategy etc and on the applications side of it [1]. In this research paper we will cover Machine learning techniques from both these aspects.

Wireless sensor networks have many diverse applications – military surveillance, monitoring of building structures and patient monitoring along with fault detection and location tracking.

Current applications can deploy such sensors on a large scale[2]. In this paradigm, large amounts of data are transmitted, processed and received by base stations, which limits the computations due to the limited energy of the sensors and also constraints of bandwidth. The objective therefore of Machine Learning techniques is to lessen the data communicated and distribute the computations in the wireless sensor network.

In this survey paper, machine learning techniques to increase network performance and processing of information within a wireless sensor network are surveyed and discussed. The rest of the paper discusses the scope for further work in this area and the paper ends with concluding remarks about the work.

II. Machine Learning Techniques : A networking perspective.

In this section we discuss Machine Learning Techniques from the perspective of three critical areas of study:

- Energy conservation in communication.
- Optimal Deployment of Sensor nodes.
- Resource management and Scheduling of tasks in a Wireless sensor network.

i. Energy Conservation in Communication

We would like to optimize the performance of a WSN for energy conservation so that its performance improves. This can be done through the design of more efficient routing algorithms in the network layer[3]-[5], using low power modulation in physical layer [6], and using power saving in data link layer[7]. Machine learning techniques can be applied to boost energy conservation in such communication.

WSN applications need fast and reliable data communication. There is thus a need to identify energy efficient routes in such networks. Routing optimization using supervised learning is discussed [8]. The objective of this machine learning algorithm is to optimize communications. It aims to automatically discover the mapping between input space(e.g. packet length, network metrics) and output(the optimal route). The learning process in this takes place in four steps namely:

a. Feature selection .
b. Sample collection.
c. Training(offline).
d. Classification(online).

We briefly elaborate on each of these steps now.

Feature Selection:

Feature selection is also called variable selection or attribute selection.

It is the automatic selection of attributes in your data (such as columns in tabular data) that are most relevant to the predictive modeling problem you are working on. It can be seen as the process of selecting a subset of relevant features that helps in model construction.

In WSN a feature vector comprises of network metrics like traffic pattern etc. Output labelling involves classifying the outputs .

Sample collection: The process of collecting data for Training algorithms is known as Sample collection. A centralised learning architecture is computationally heavy and so the use of a Distributed architecture is recommended for real time problems.

Training(offline): The actual learning takes place in this . Two classification algorithms – C4.5 , a Decision tree based algorithm and a rule based learner are discussed here. These algorithms use a centralized learning architecture involving a back end server and therefore learning overhead is high. Therefore a distributed learning architecture is preferred as it is more efficient.

In [9] the use of a Reinforcement learning paradigm is made for energy conservation in wireless sensor networks. The aim is to have average through put maximization per total energy used. In this paradigm, the optimal modulation level and transmission power are sought to be adjusted according to the input network traffic and the channel constraints. Machine learning can maximize the channel throughput by generating an optimal transmission policy.

Fuzzy logic in sensor communications id discussed by the authors in [10,11]. In order to increase adaptability of sensor types and have diverse applications, it is necessary to complement crisp metrics by imprecise and fuzzy data which use heuristics to generate the output.

Fuzzy logic is used to get the cost of a link between two sensor nodes such that the network lifetime is maximized. In this process, transmission energy, energy consumption rate, queue size etc are input variables while link cost is the output fuzzy set. The link cost is got as a crisp value utilising defuzzification. A fuzzy logic controller is used at each sensor node to get the capacity to transfer packets of data in the wsn. The input variables to the fuzzy controller are type of data packet etc. The sensor nodes will be either participants or be inactive in communication of data based on the output of the fuzzy controller that is a crisp value.

ii. Optimal Deployment of Sensor Nodes:

The deployment of sensor nodes and localization of these are important research problems in this area.

The Deployment problem in wsn means to select an optimal distribution of nodes such that information gain from them is maximized.

A fuzzy logic based deployment scheme has been described in the paper discussed in [12] for the purpose of surveillance. Since terrain profiles are not homogeneous an area may need more number of sensors. The area of concern is segregated into sub areas, each having its own terrain profile and a fuzzy system computes the number of nodes in each sub area. The fuzzy logic based system achieves a higher coverage and greater information gain.

Sensor nodes are initially deployed randomly and there after a fuzzy optimization algorithm adjusts the nodes to get higher information gain.

The authors in [14] get an improved optimal placement model with maximum gain in information and minimum communication overheads.
Localization refers to a nodes location in order to localize information. There are two broad approaches – Hardware and Probability based estimation.

A fuzzy logic based system for node localization[15] uses a grid approach in which a nodes location is determined by application of fuzzy rules, in which its location on the grid is indicated by a confidence level.

The use of Genetic algorithms in localization is proposed by [16], in which a Genetic algorithm optimizes the output of a localization algorithm there by improving its efficiency greatly.

iii. Resource Management and Scheduling :
This is more of a global process in which the objective is to see how a group of sensor nodes can be managed and scheduled to attain a system objective.

Three algorithms for task scheduling in radar sensor networks are compared in [17]- Fuzzy lyapunov synthesis, genetic algorithms and Neural Networks(NN). It is shown that Genetic algorithms(GA) perform best .

An adaptive distributed resource allocation scheme for system nodes is described in [18],[19]. In this paradigm, each node adapts its operations in time after taking into account the status and feedback of its neighbours. The applications include field surveillance using an acoustic wsn and a camera network for traffic monitoring.

A fuzzy logic system for electing the cluster head in a wsn is described in [20]. The cluster head election is a resource allocation problem. Based on three inputs of node energy, node concentration and centrality in the cluster , the output decision is which node becomes the cluster head.

III. Machine Learning Techniques in Inferencing in WSN

Figure 1 : Information Processing in Wireless Sensor Network.

The three phases of information processing in a wsn are outlined in figure 1 above.
Preprocessing: Actions on raw data e.g. smoothing, noise filtering etc.

Data Aggregation: Aggregating data to the inference centre in a wsn.

Inferencing: Applying Machine learning techniques on aggregated data to find patterns.

Sample applications include object classification in a wsn based on sensor data, natural event detection in an environment based wsn, fault detection using a distributed grid based wsn deployment etc.

Now we describe some important applications of Machine learning techniques in Wireless sensor networks.

- Monitor dynamic environments that change rapidly over time.

(Ex. monitor a node's geographical location).

- Calibrate a WSN to new knowledge about the environment

(Ex. volcano eruption and waste water monitoring).

- Modelling systems with high complexities/dimensions that make it difficult for mathematicians to model.

- Extract important correlations between sensor data to propose further improvements to the system.

- Intelligent decision making and autonomous control.

- Target Tracking in Wireless sensor networks: This involves tracking moving objects through a surveillance based system, including tracking of multiple targets.

- Classifying Events : This process involves classifying a tracked object according to its type- e.g detection of a storm through a surveillance system. Neural Networks are being used in this classification process . Similarly human motion can also be studied through capturing movement information through a body based sensor network. This data can then be analysed by using various techniques like prinicipal component analysis(pca), support vector machines(svm) and clustering algorithms.

IV. Further Work in Machine Learning Applications with respect to Wireless sensor Networks

a. Data compression to reduce dimensionality and extend the network lifetime.

b. Distributed Machine Learning Architectures for WSN: This enables sensor nodes to become more adaptive to its environment and reduces computational overhead.This is so as memory overheads are lower as these do not have to consider the entire network information.

c. Resource Management in Wireless sensor Networks: The objective is to conserve energy which can be done by routing optimization. Optimization of resource management and power allocation can be done by using machine learning techniques .

d. Hierarchial clustering of sensor Nodes: This clustering can be used to build a hierarchy of clusters. In this only one node from a cluster can be activated at a time to monitor the whole cluster area.

V. Conclusions
In this survey paper we have described some issues in the application of Machine learning techniques in Wireless sensor networks. Such techniques can be used for energy conservation, sensor localization, and resource management in WSNs. In respect of inferencing in WSN using machine learning techniques, some key applications have been described in this research paper.

The scope for further work in this domain is also stated.

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